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**Ulrich et al.**

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(54) **PERSONNEL AND ASSET TRACKING  
METHOD AND APPARATUS**

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This patent is subject to a terminal dis-  
claimer.

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#### ABSTRACT

A system is provided for locating and tracking tags within an  
awareness area including a first sub-awareness area and a  
second sub-awareness area. Each tag includes a transmitter  
configured to transmit a unique identifier periodically, and at  
least one tag is assigned to the first sub-awareness area. The  
system includes a first monitoring system associated with  
the first sub-awareness area and a second monitoring system  
associated with the second sub-awareness area.

79 Claims, 13 Drawing Sheets

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2000, which is a continuation of application No. 08/963,396,  
filed on Nov. 3, 1997, now abandoned.

(51) **Int. Cl.**<sup>7</sup> ..... G08B 1/08

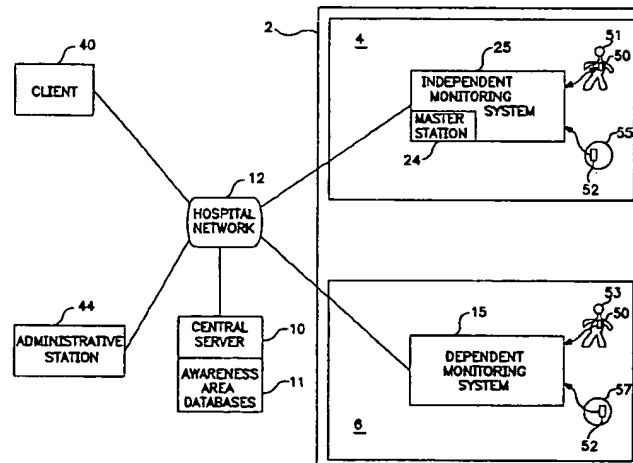
(52) **U.S. Cl.** ..... 340/539; 340/573.1; 340/573.4;  
340/825.36; 340/825.49

(58) **Field of Search** ..... 340/539, 573.1,  
340/825.36, 825.49, 573.4

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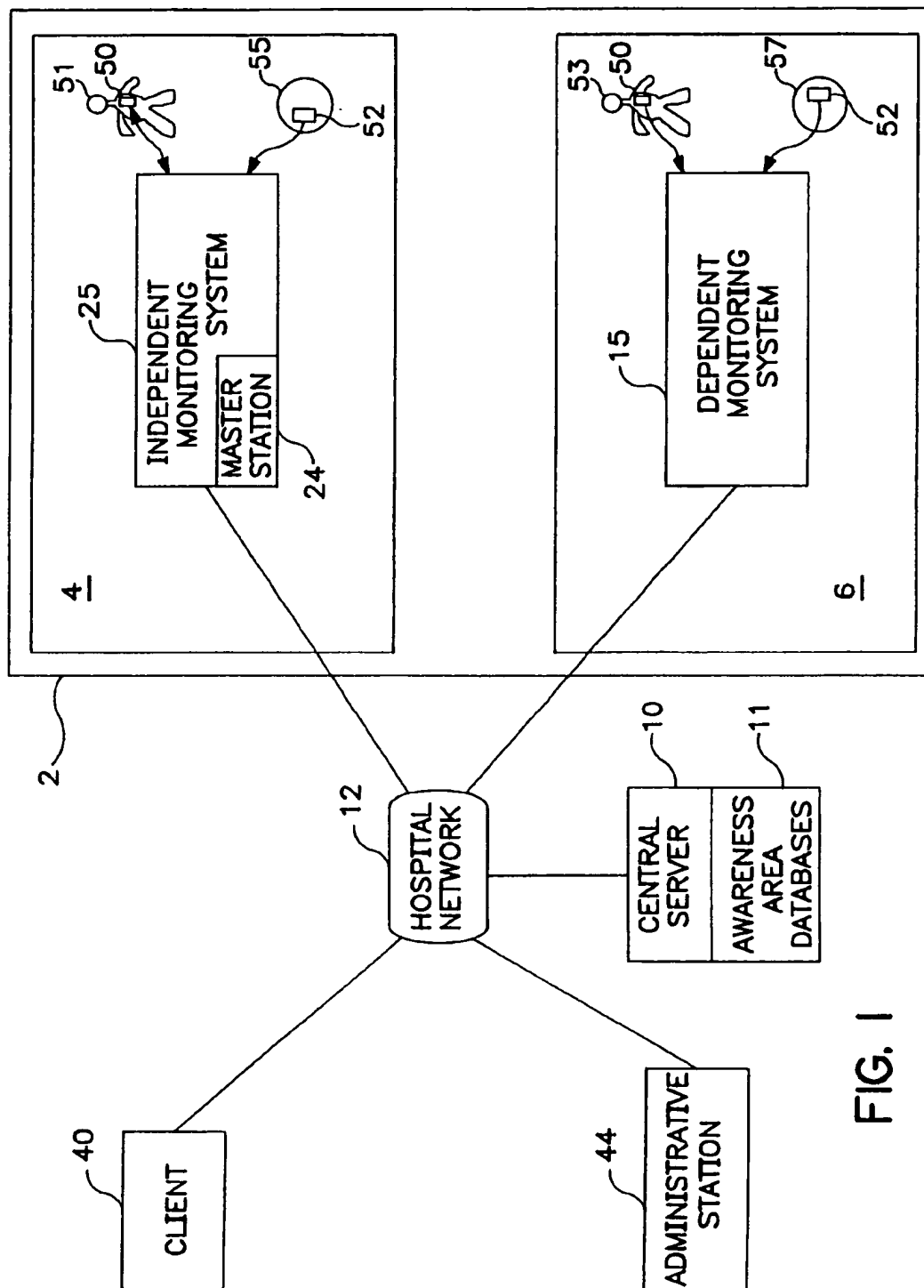


FIG. 1

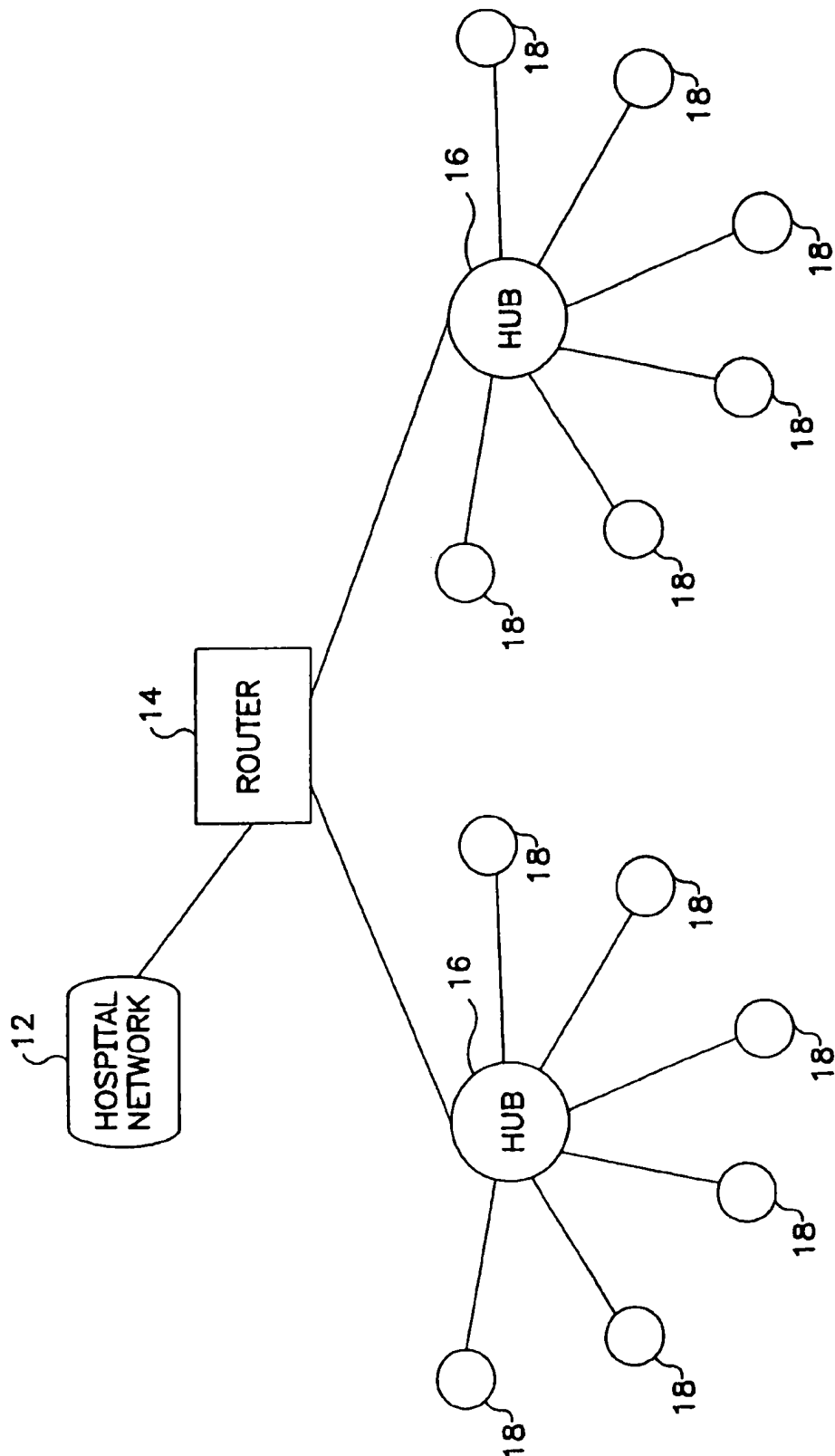


FIG. 2

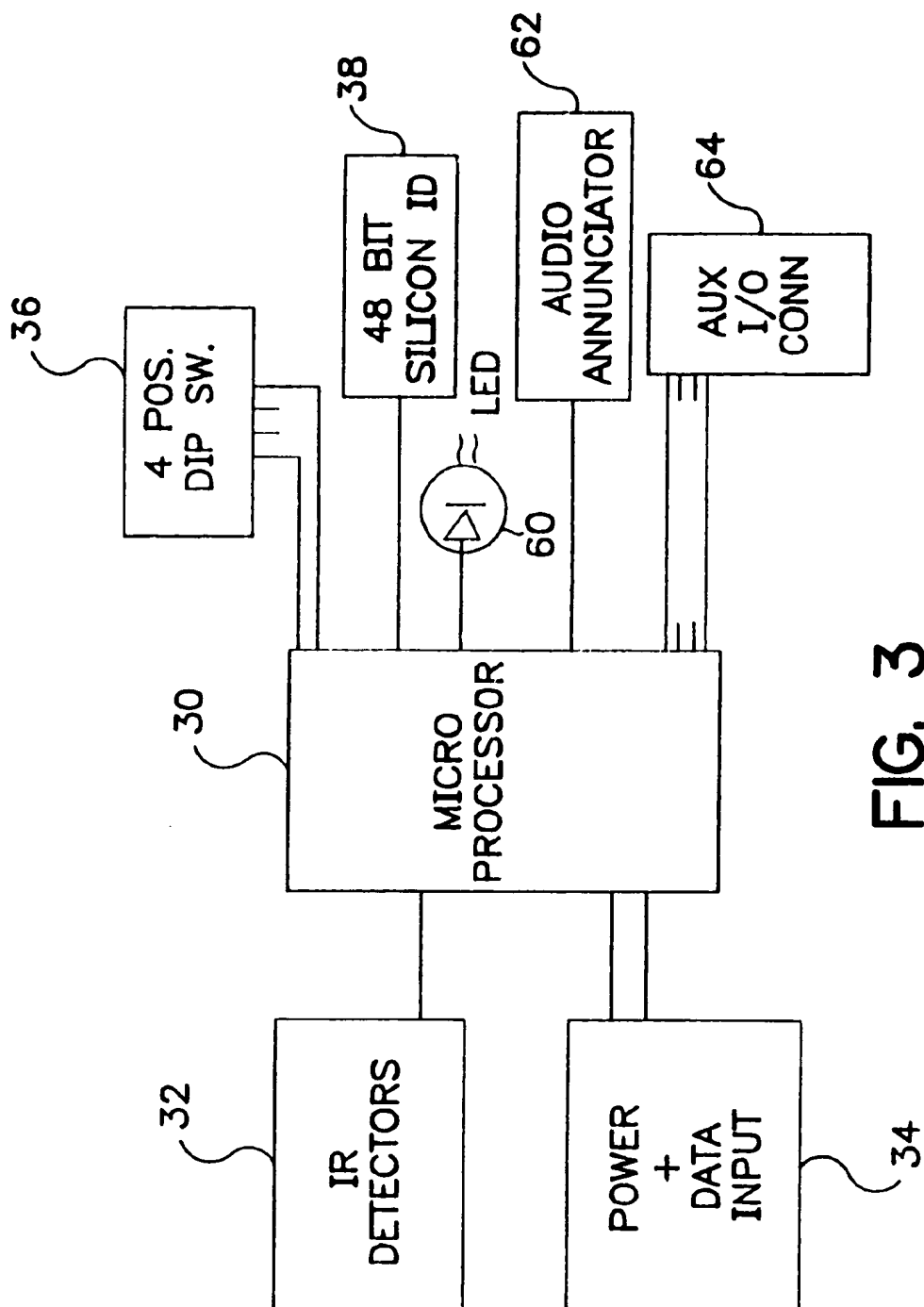
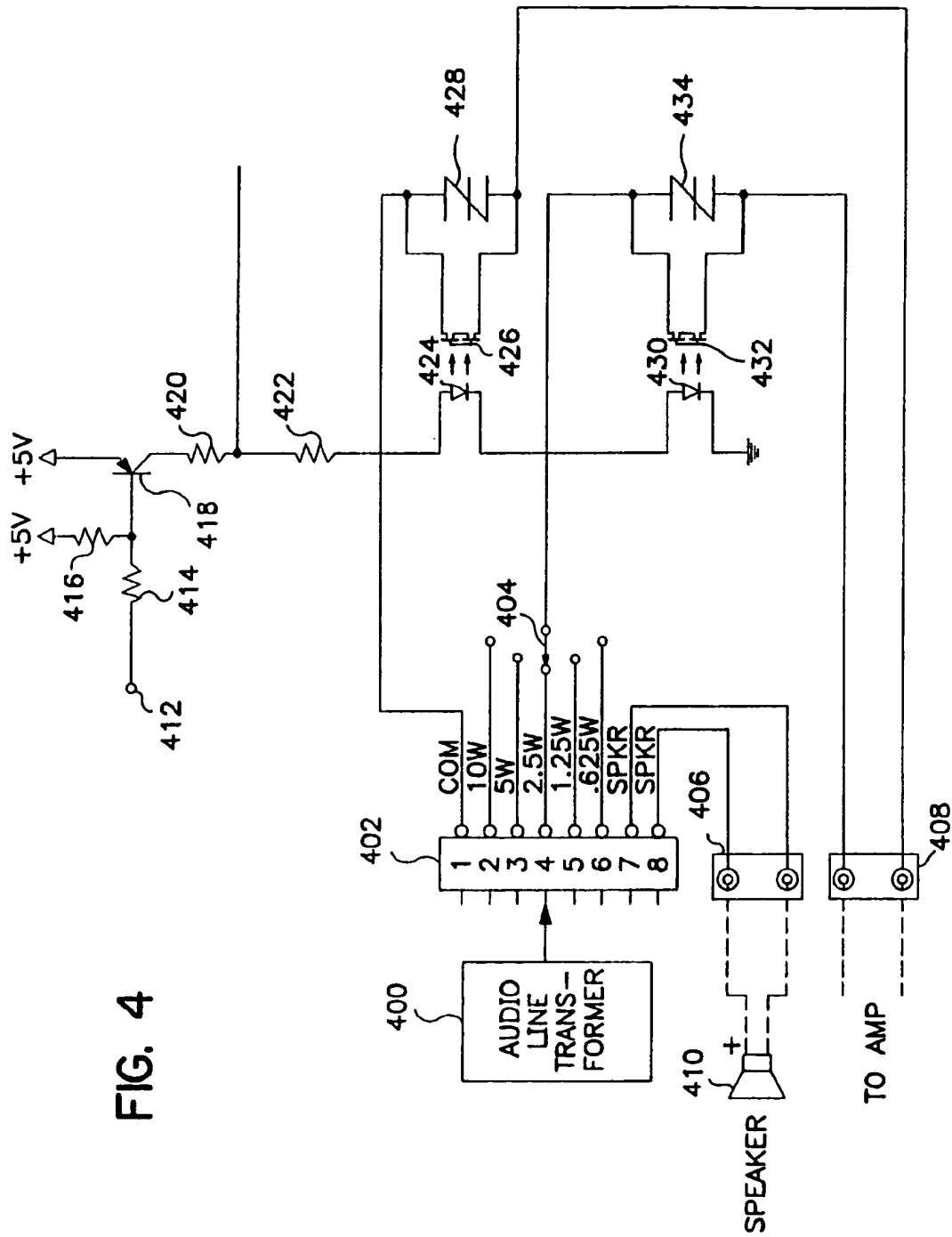


FIG. 3

FIG. 4



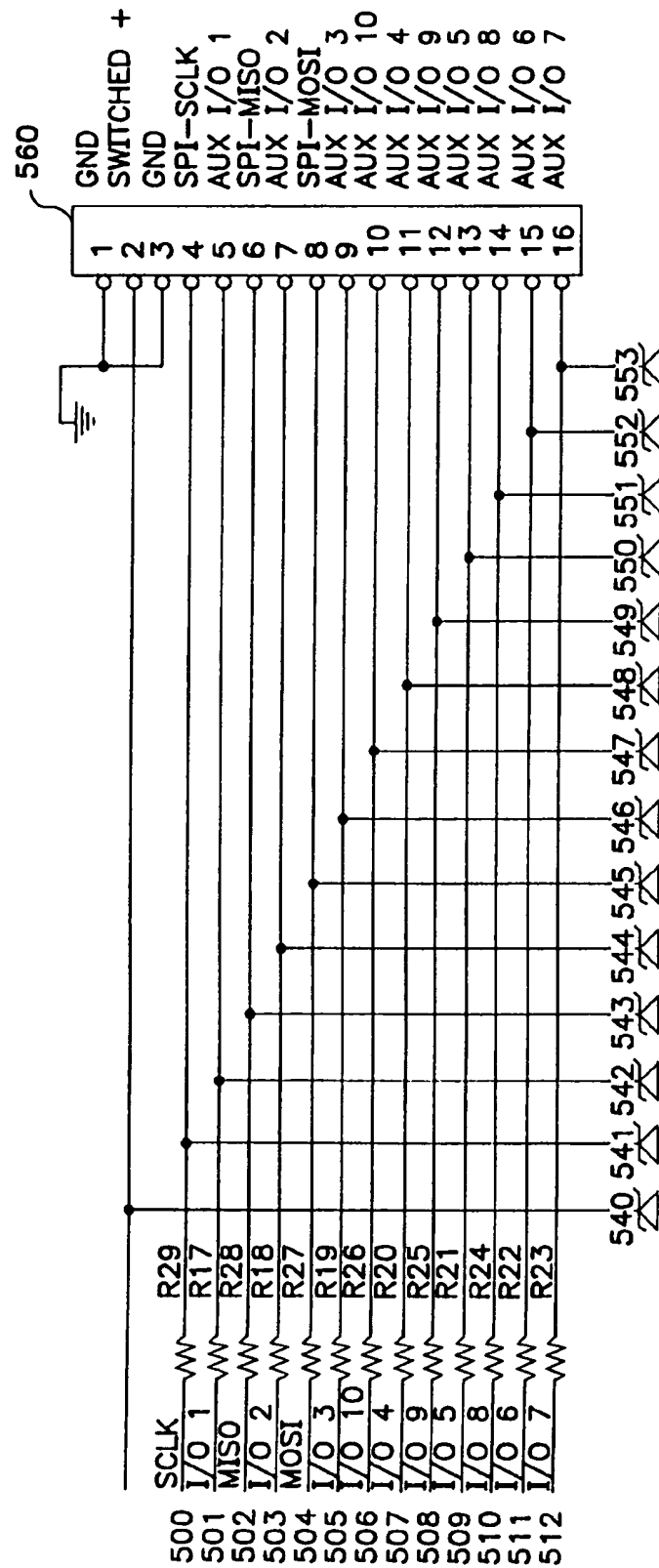


FIG. 5

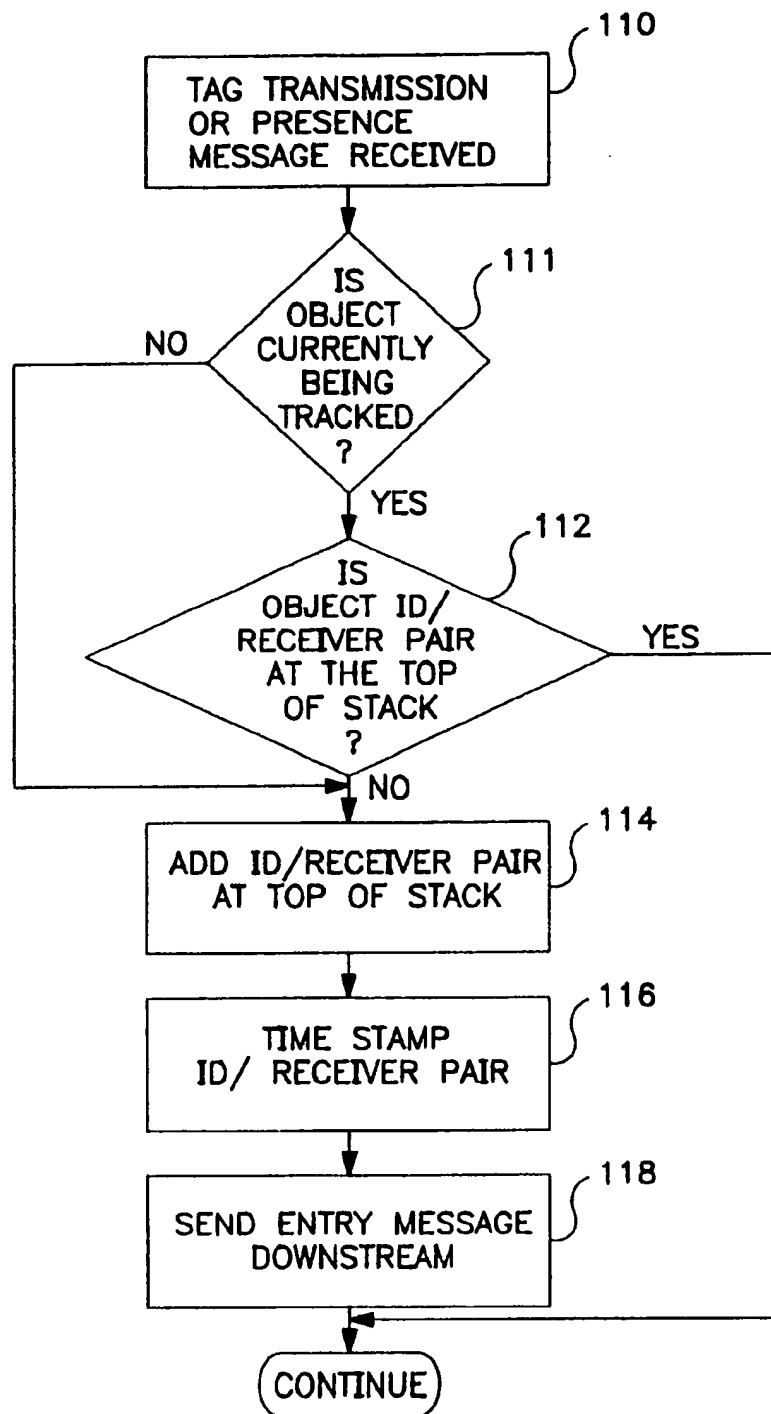


FIG. 6



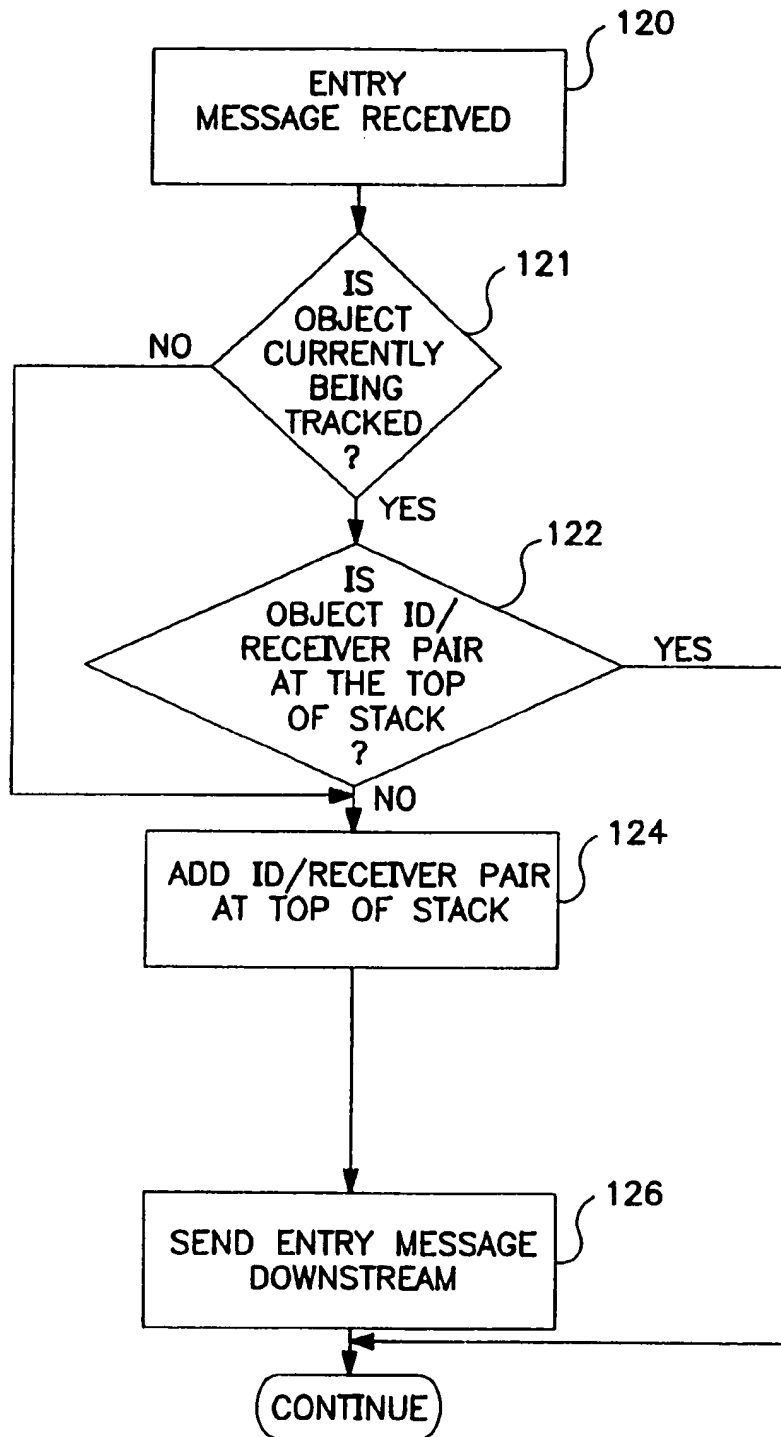


FIG. 7

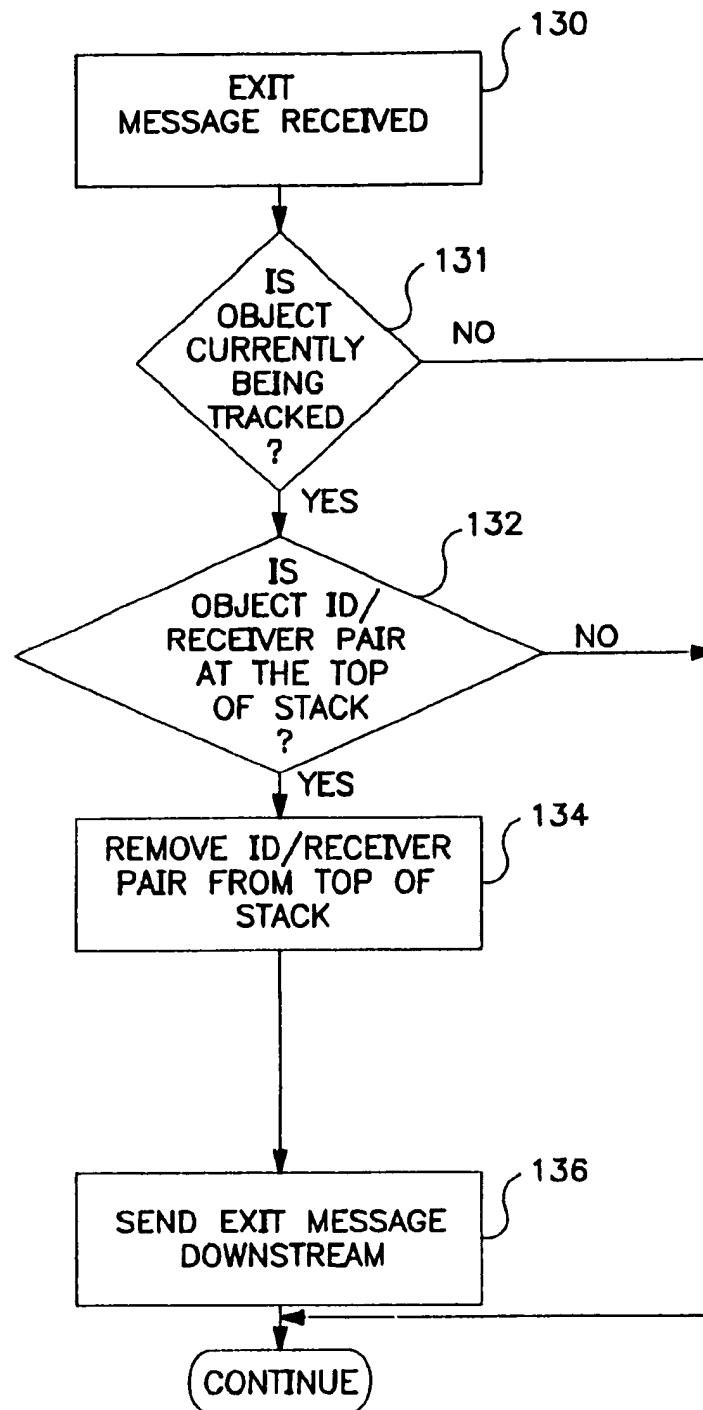


FIG. 8

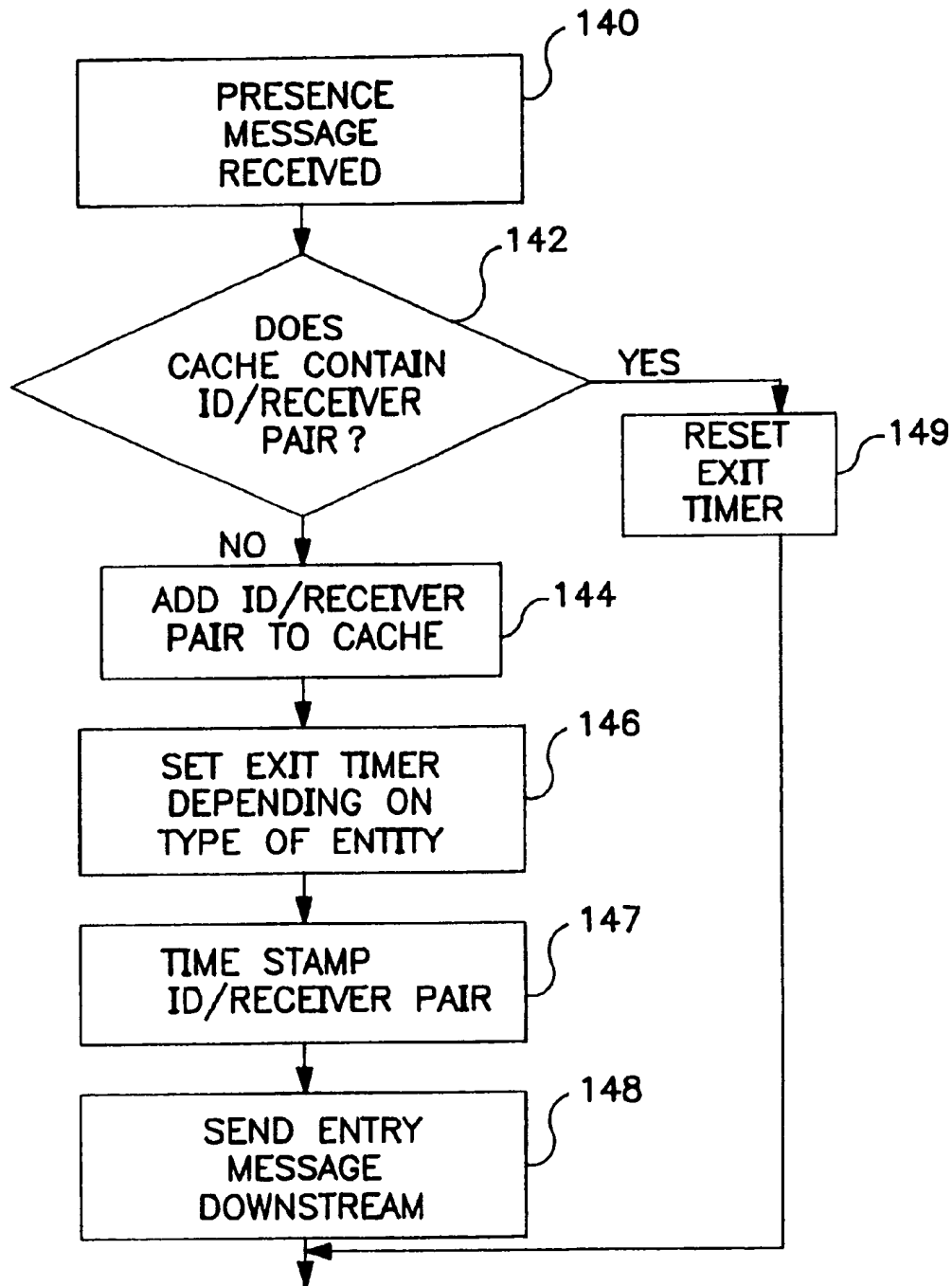


FIG.9

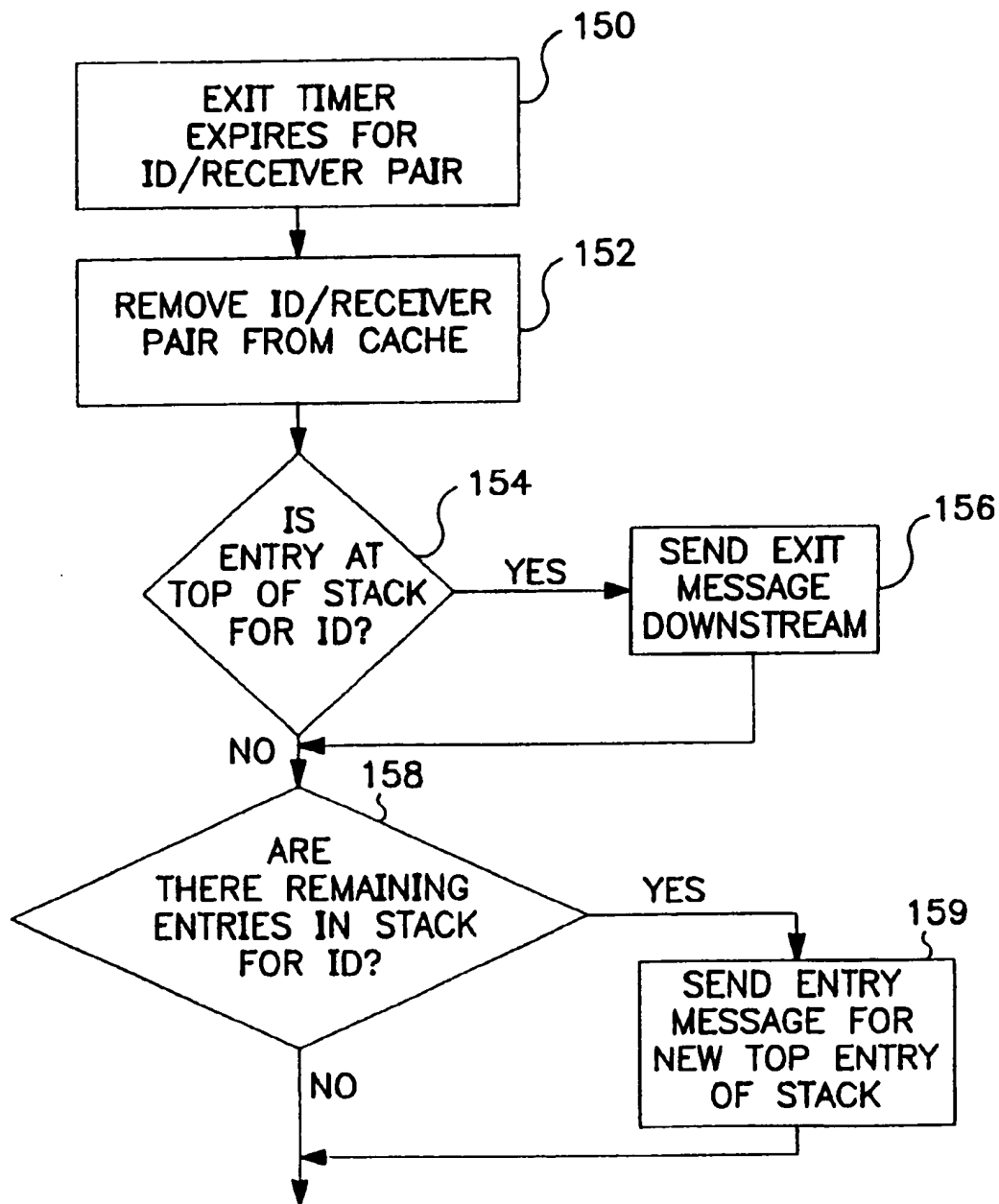


FIG. 10

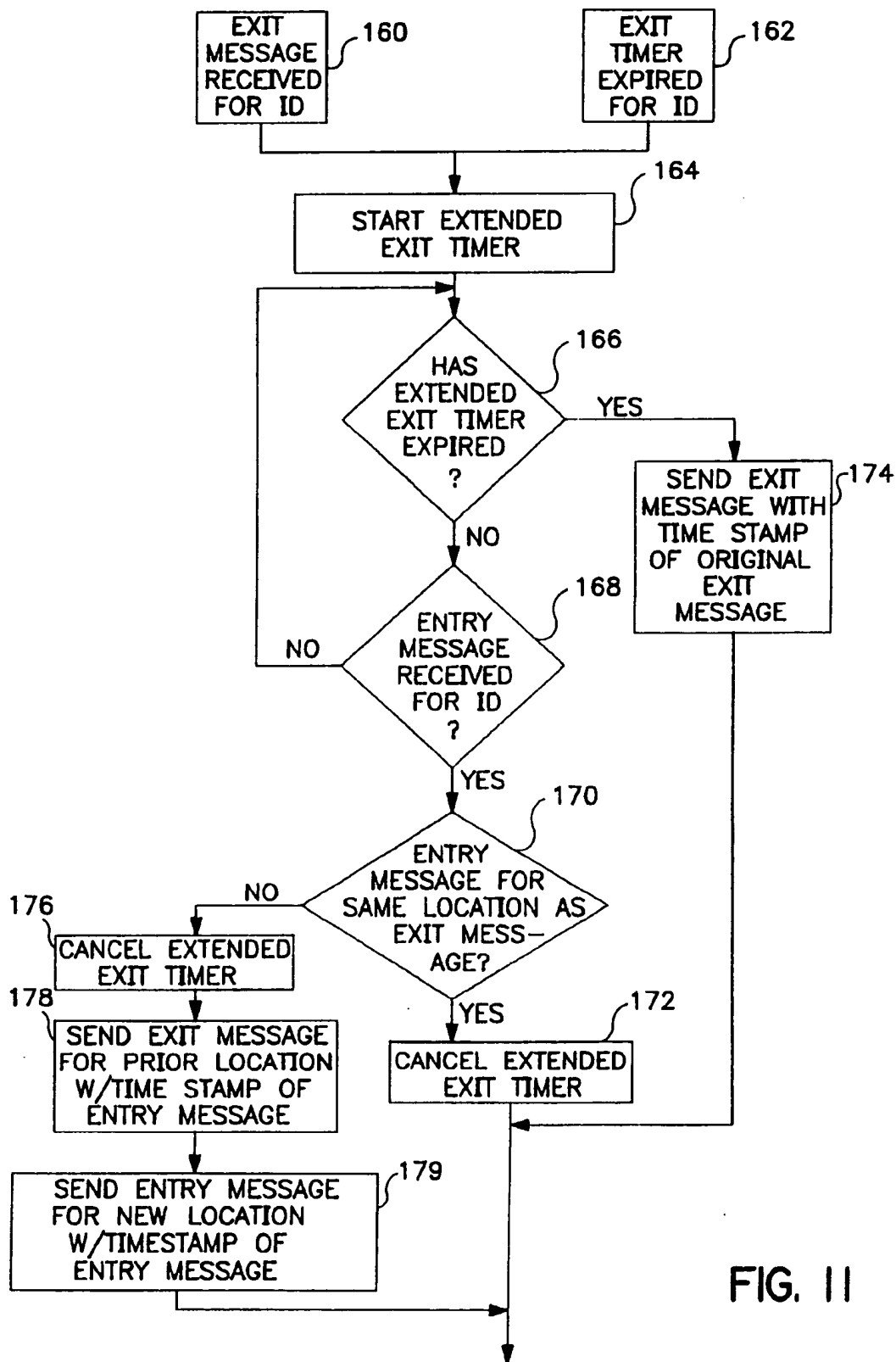


FIG. 11

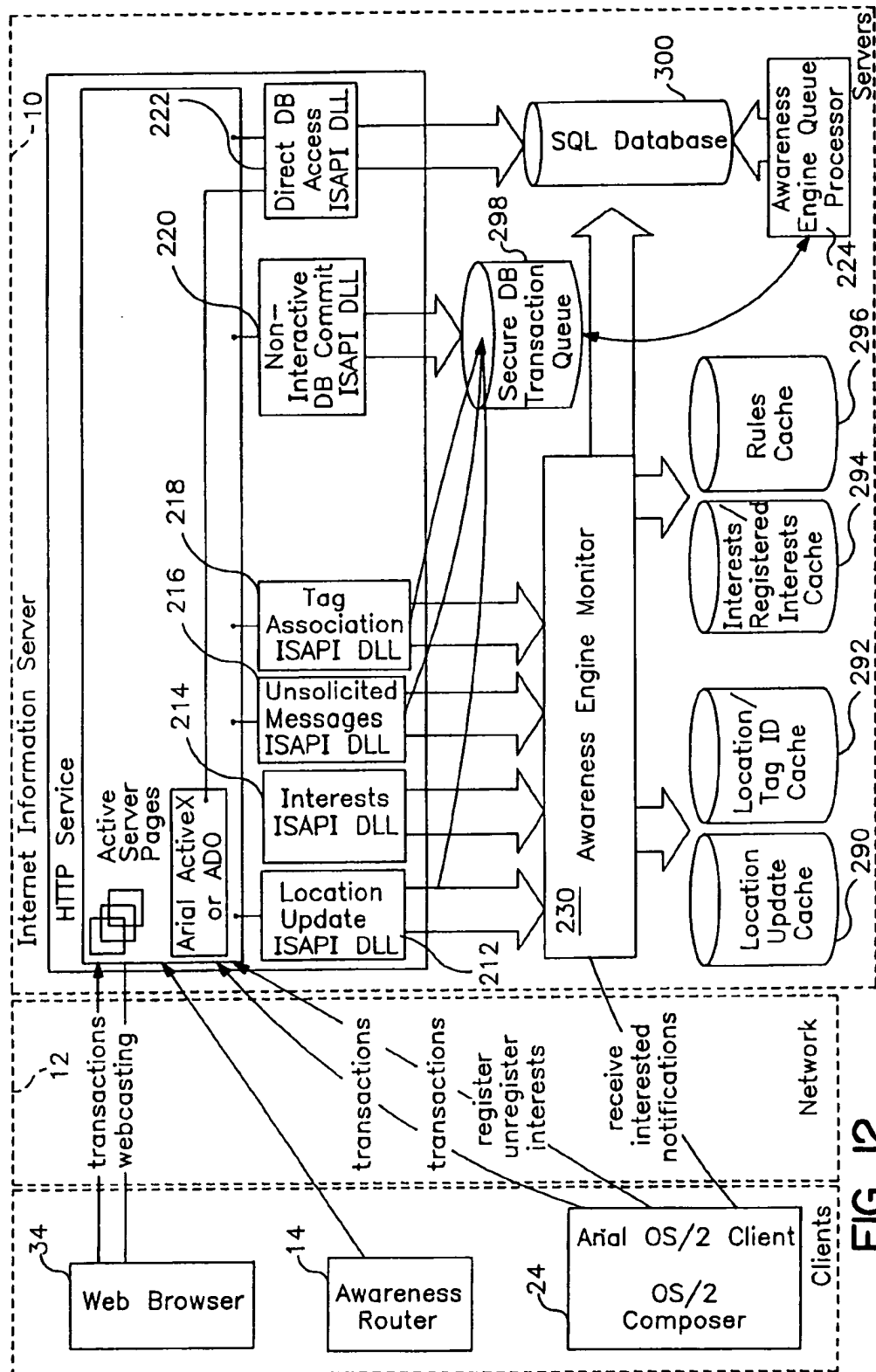
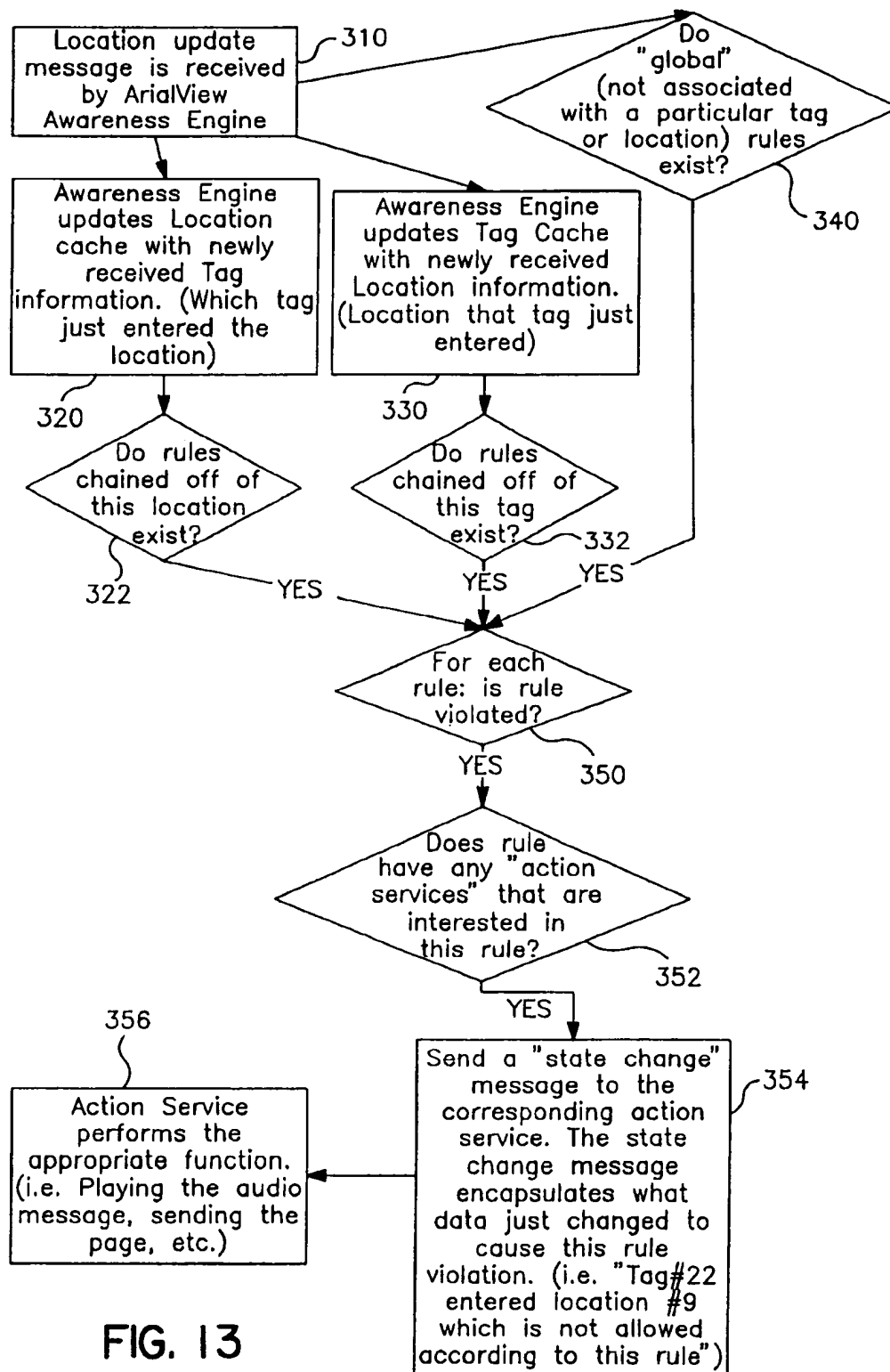


FIG. 12



## PERSONNEL AND ASSET TRACKING METHOD AND APPARATUS

### RELATED APPLICATIONS

This is a continuation of application Ser. No. 09/479,359 filed on Jan. 7, 2000, which is a continuation of application Ser. No. 08/963,396 filed on Nov. 3, 1997, now abandoned.

### TECHNICAL FIELD OF THE INVENTION

This invention relates to a system for tracking personnel and assets over an extended area composed of one or more sub-areas which are monitored by sub-area monitoring systems. The sub-area monitoring systems communicate with and update location databases resident on a common central server. Clients communicate with and access the databases of the central server via an Internet web browser interface.

### BACKGROUND OF THE INVENTION

Location and tracking systems using object tags, a plurality of receivers located at known locations and a central computer are well known in the art. The tags periodically transmit a unique ID signal which is received by the receivers and the central processor combines the receiver location with the tag ID to determine the location of the object associated with the tag. However, these systems have several limitations. Location data maintained by the central processor has limited accessibility from locations other than the central processor. All location data is maintained by the central processor. Any location monitoring devices that send location data to the central processor must be specifically designed to work with the central processor, and must be like all the other location monitoring devices connected to the central processor. All of the location data must be sent to the central processor and anytime communication with the central processor is lost the location data collected by the disconnected location monitoring devices is inaccessible. The central processor receives location updates but does not forward location data to other monitoring systems.

### SUMMARY OF THE INVENTION

An illustrated embodiment of the present invention includes a central location database that can be accessed from any computer with network access to the central server through Intranet or Internet using a standard web browser interface. The web browser interface is illustratively created using a Microsoft technology called Active Server Pages and the programming language VBScript. Active Server Pages allow the creation of dynamic web pages which are tailored according to the requests of the client queries. The dynamic server pages are interpreted by the web browser to provide virtually complete access to the location databases and other databases maintained on the central server. Any computer with communications network access to the central server and supporting a web browser interface can access the location data and other data stored on the central server.

The illustrated embodiment of the present invention allows the tracking and locating of objects over a large area by combining the object transmissions received over multiple sub-areas which are monitored by autonomous monitoring systems interconnected through a communications network. Each location monitoring system sends the location updates to the central server over the communications network. The central server can maintain location data for a large area by receiving location updates over several sub-areas which each have a location monitoring system tracking

object tags in their particular sub-area. The area and sub-areas could be a building and its floors, a campus and its buildings, or several campuses and the floors of each of the buildings on each of the campuses. The sub-area monitoring systems only have to be able to track the same tags and have access to the central server over a communications network for a client connected to the central server to obtain location information on an object anywhere in the awareness area.

The illustrated embodiment of the present invention supports locating and tracking over the entire area using both dependent locating and tracking system, locating and tracking systems which depend upon the central database to store location data and to respond to database queries, and independent locating and tracking systems, locating and tracking systems which forward location data to the central server as well as maintaining local sub-area location databases. Each of the sub-area monitoring systems can either send all data to the central server for recording, a dependent monitoring system, or have a local database for objects assigned to the local sub-area and also send location updates to the central server, an independent monitoring system. If either monitoring system loses communication with the central server it will store location updates to transmit when communication is restored. An independent monitoring system will continue to support local location queries for the objects assigned to its sub-area when communication is lost with the central server. The central server can also pass location updates and messages back to the independent monitoring systems. If an object assigned to sub-area A is in another sub-area monitored by the central server then location updates can be recorded at the central server and forwarded to sub-area A to keep the local database updated even when the objects are outside sub-area A. The independent monitoring system can also assign new tags to the sub-area and receive updates from anywhere monitored by the central server. However, when communication with the central server is lost only objects within the sub-area can be tracked.

Additional advantages and features of the invention are set forth in the description that follows, and will become apparent to those skilled in the art upon reviewing the drawings in connection with the following description.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the layout of the personnel and asset tracking system.

FIG. 2 shows the interconnection of the components of a dependent monitoring system.

FIG. 3 shows the interconnection of the components of a receiver node.

FIG. 4 is a detailed design of the receiver node audio annunciator.

FIG. 5 is a detailed design of the receiver node auxiliary I/O connector.

FIG. 6 shows the procedure used by a location processor for processing a presence message.

FIG. 7 shows the procedure used by a location processor for processing an entry message.

FIG. 8 shows the procedure used by a location processor for processing an exit message.

FIG. 9 shows the procedure used by a location processor for processing a presence message when the location processor has exit timer capability.

FIG. 10 shows the procedure used by a location processor when an exit timer expires.

FIG. 11 shows the procedure used by a location processor for processing an exit message or the expiration of an exit timer when the location processor has an extended exit timer.



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FIG. 12 shows a block diagram of the central server web browser interface and the associated application programs and databases on the central server with connection to clients.

FIG. 13 is a flowchart of the rules processing by the Awareness Engine Monitor when a location update message is received.

#### DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the interconnection of the primary components of the personnel and asset tracking system. The heart of the system is the central server 10 which maintains the awareness area databases 11 for the system over the entire area in which awareness of personnel and assets is to be monitored, the awareness area 2. The central server 10 receives location and status updates from at least one monitoring system through a communications network 12. Each monitoring system monitors personnel and assets throughout a sub-area of the awareness area, a sub-awareness area. FIG. 1 shows an independent monitoring system 25 monitoring a sub-awareness area 4 and a dependent monitoring system 15 monitoring another sub-awareness area 6. Both the dependent monitoring system 15 and the independent monitoring system 25 send location updates to the central server 10 over the network 12. The dependent monitoring system 15 does not maintain a local database, and thus depends on the central server 10 to handle location queries from clients 40. The independent monitoring system 25 maintains a local sub-awareness area 4 location database on the master station 24, and thus can support local queries for objects assigned to it independent of the central server 10. The independent monitoring system 25 receives signals transmitted by a personnel badge 50 worn by a person 51 and an asset tag 52 attached to an asset 55. The dependent monitoring system 15 receives signals transmitted by another personnel badge 50 worn by a person 53 and another asset tag 52 attached to an asset 57. An awareness area 2 and sub-awareness areas 4, 6 could be a building and its floors or a campus and its buildings. Each entity to be monitored in the awareness area 2 wears a personnel badge 50 or an asset tag 52 which transmits a unique object ID signal.

Access to the awareness area databases 11 maintained at the central server 10 can be gained from a client 40 or an administrative station 44 through the network 12. Client 40 can be connected to the network 12 locally (e.g. Intranet) or remotely (e.g. Internet). Independent monitoring system 25 can also access the awareness area databases 11 maintained on the central server 10 through the hospital network 12.

There are two types of sub-awareness area monitoring systems. A dependent monitoring system 15 is connected to the hospital network 12 through a router 14 as shown in FIG. 2. A dependent monitoring system 15 does not maintain sub-awareness area databases or support sub-awareness area queries but rather forwards all information to the central server 10. A dependent monitoring system 15 is comprised of a router 14, at least one hub 16 and a plurality of nodes 18. Each node 18 continuously monitors a particular area in the sub-awareness area for personnel badge 50 and asset tag 52 transmissions. Each node 18 communicates with and sends location messages to a hub 16. The hub 16 communicates with and sends location messages to the router 14. The router 14 communicates with and sends location messages to the central server 10 over the hospital network 12.

The second type of sub-awareness area monitoring system is an independent monitoring system 25 as disclosed in U.S.

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Pat. No. 5,561,412 which is hereby incorporated by reference. An independent monitoring system 25 has a set of personnel badges 50 assigned for which it maintains a local database on its master station 24 which also supports local queries and status messages. The master station 24 communicates with the central server 10 over the hospital network 12.

In either type of monitoring system the process is triggered by the reception of a personnel badge 50 or asset tag 52 transmission at a receiver node 18. The receiver node 18 generates a presence or entry message which is sent to a downstream location processor. A detailed diagram of the receiver node 18 is shown in FIG. 3. The receiver 18 includes a microprocessor 30. The receiver 18 of a dependent monitoring system 15 receives power and data inputs 34 from the hub 16. The dip switches 36 are used to configure the receiver 18 for use with either a dependent monitoring system 15 or an independent monitoring system 25. The multiple infrared detectors 32 receive the transmissions of personnel badges 50 and asset tags 52 and relay them to the microprocessor 30, which processes the badge transmissions and can forward a location message to the next upstream location processor over the data lines 34. The 48 bit silicon ID is set to a unique address to identify the node 18. The node 18 also has a LED 60, an audio annunciator 62 and an auxiliary I/O connector 64.

A detailed drawing of the audio annunciator 62 is shown in FIG. 4. If the audio annunciator 62 of the node 18 is selected then a control signal will be sent by the microprocessor 30 at the connection 412 through the resistor 414. A resistor 416 ties the base of the transistor 418 to the voltage source. The control signal from the transistor 418 passes through resistors 422 and 420 to activate the audio switches 424, 430 and the audio line transformer 400. The audio signal is input from an audio amplifier over connector 408. The audio input is processed simultaneously by two parallel and totally isolated audio switches. The audio signal passes across a pair of optically isolated FET switches 424, 430 which transmit an optical signal to the photo-transistors 426, 432 which are each in parallel with a noise suppression diode 428, 434. The output audio signal is input to the audio line transformer 400 through connector 402. The output of the audio line transformer 400 is sent through connectors 402 and 406 to speaker 410. Switch 404 controls the volume of the signal sent to speaker 406.

A detailed diagram of the auxiliary I/O connector 64 of the node 18 is shown in FIG. 5. The auxiliary I/O connector 64 is connected to the microprocessor 30 through the lines 500-512. Each line to the microprocessor 30 is protected by a current limiting resistor 517-529 and a zener diode clamp 540-553 to protect from reverse or over-voltages. Each line is also connected to an input/output line at connector 560. These auxiliary lines could be used for inputs or outputs. Examples of inputs are monitoring room temperatures or the presence of persons without a personnel badge or for outputs. Examples of outputs are thermostat controls, light controls or buzzers.

#### Inter-Location Messages

Both a dependent monitoring system 15 and an independent monitoring system 25 is comprised of an infrastructure with multiple location processor levels. The most upstream location processors are the nodes 18 which receive the badge/tag transmissions and pass them downstream and generate the initial location messages. These location messages are passed downstream to intermediate location processors which pass the location messages to the downstream location processors which are either a router 14 or a master

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station 24 that passes the location message to the central server 10. A location message begins with the reception of an object ID from a personnel badge 50 or asset tag 52 transmission and ultimately ends with the updating of a database 11 such that the best location data is available for all objects being tracked. A location processor can function in either a pass-through or a buffered mode. In pass-through mode any location message received by the location processor is passed to the next location processor in the stream leading to the central server 10. In buffered mode the location processor maintains a cache with a stack for each object ID it is currently tracking and only passes along changes in the status of a particular object ID. The inter-location messages in buffered mode can be either presence messages, entry messages or exit messages, while the inter-location messages in pass-through mode are presence messages. Each of these messages is for a particular personnel badge 50 or asset tag 52 object ID at a particular awareness area location. Entry and exit messages also have a time stamp associated with them identifying the time the event occurred.

A presence message simply indicates that a particular object ID is present at a particular awareness area location. A presence message is generated at a node 18 when it receives a personnel badge 50 or asset tag 52 transmission or is received at a downstream location processor from an upstream pass-through location processor. The processing of a presence message by the first buffered location processor is shown in FIG. 6. The process is initiated by the reception of a tag transmission at a node 18 or the reception of a presence message from an upstream location processor 110. The location processor receiving the presence message checks if it is currently tracking this object ID 111. If the object ID is currently being tracked, the location processor checks if the top entry in the stack for this object ID already shows the same location as the presence message 112. If the top entry of the stack already contains this object ID and receiver pair then there is no change in the object's location and no further processing is required. If its cache does not contain this object ID or it shows a different location then there has been a location change for this object. The location processor adds the object ID and receiver pair to the top of the stack for the object ID in its cache 114, time stamps the message 116, and sends an entry message to the next downstream location processor 118.

An entry message indicates the transition of an object ID from not being detected at a particular location to being detected at that particular location. An entry message is created by an upstream location processor and sent downstream. The processing of an entry message is shown in FIG. 7. This process is initiated by the receipt of an entry message 120. The location processor receiving the entry message checks if it is currently tracking this object ID 121. If the object ID is currently being tracked, the location processor checks if the top entry in the stack for this object ID already shows the same location as the entry message 122. If the top entry of the stack already contains this object ID and receiver pair then there is no change in the object's location and no further processing is required. If its cache does not contain this object ID or it shows a different location then there has been a location change for this object. The location processor adds the object ID and receiver pair to the top of the stack for the object ID in its cache 124, time stamps the message 126, and sends an entry message to the next downstream location processor 128.

An exit message indicates the transition of an object ID from being detected at a particular location to not being

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detected at that particular location. An exit message is created by an upstream location processor and sent downstream. The processing of an exit message is shown in FIG. 8. This process is initiated by the receipt of an exit message 130. The location processor receiving the exit message checks if it is currently tracking this object ID 131. If the object ID is currently being tracked, the location processor checks if the top entry in the stack for this object ID already shows the same location as the presence message 112. If top entry does not contain this object ID and receiver pair then the object ID is not associated with the location and no further processing is required. If the top entry of the stack contains this object ID and receiver pair then the object ID and receiver pair is removed from the cache 134 and the exit message is sent to the next downstream location processor 136.

Buffered location processors can maintain up to two timers related to exit processing. The first, an exit timer is kept at the most upstream buffered location processor which could be a node 18 receiving object ID transmissions from a personnel badge 50 or asset tag 52, or a downstream location processor receiving presence messages from an upstream pass-through location processor. The exit timer is used to generate an exit message if presence messages are not received for a particular object over a predetermined time interval.

The initialization of an exit timer for a particular object ID is shown in FIG. 9. The process is initiated by the receipt of a presence message 140. The location processor receiving the presence message checks if its cache already contains this object ID and receiver pair 142. If its cache already contains this object ID and receiver pair then the exit timer is reset 149 and no further processing is required. If the cache does not contain this object ID and receiver pair then an entry condition has taken place for this object. The location processor adds the object ID and receiver pair to its cache 144, sets the exit timer for this object depending on whether it is a personnel badge 50 or asset tag 52 transmission 146, time stamps the object ID and receiver pair 147, and sends an entry message to the next downstream location processor 148.

The process that occurs when the exit timer expires for a particular object ID and location pair is shown in FIG. 10. This process is initiated by the expiration of the exit timer 150 which indicates that no presence messages have been received by the location processor since the exit timer was last set, and therefore the object is assumed to have left the location it was last associated with by this location processor. When the exit timer expires the object ID and receiver pair is removed from the cache 152. The location processor then checks if the object ID/location pair associated with this exit timer is at the top of its cache 154. If this pair is at the top of the stack an exit message is sent downstream 156. The location processor then checks if there are remaining entries in the stack for this object ID 158. If there are remaining entries, an entry message is sent downstream for the new location at the top of the cache for this object ID 159.

The second timer associated with exit message processing is an extended exit timer. An extended exit timer further delays the sending of an exit message downstream as shown in FIG. 11. Extended exit timer processing is initiated by the receipt of an exit message 160 or the expiration of an exit timer 162, either of which starts the extended exit timer 164 if the location processor is equipped for this processing. The location processor will then check for the expiration of the extended exit timer 166. If the extended exit timer expires before the receipt of an entry message for the particular

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object ID then an exit message is sent downstream with the time stamp of the original exit message 174 and no further processing is required. If an entry message is received for the particular object ID before the extended exit timer expires 168 then the location processor checks if the location of the entry message is the same as the object ID/location pair associated with the extended exit timer 170. If the location is the same then the object has not changed location and the extended exit timer is canceled 172 and no further processing is required. If the location is different then the object has changed location; the extended exit timer is canceled 176, an exit message is sent for the location associated with the extended exit timer with the time stamp of the entry message 178, and an entry message is sent for the new location with the time stamp of the entry message 179.

A downstream location processor can request an upstream location processor to send the contents of its cache showing the object IDs that the upstream location processor is tracking. The response message consists of a list of object IDs and their associated locations.

#### Action Message Processing

Each personnel badge 50 is equipped with an action button or switch which is used to send an alert signal. A unique system response can be defined for the reception of an alert signal from each personnel badge 50 tracked by the system. The primary response is maintained at the central server 10, and for an independent monitoring system 25 a secondary response can be maintained at the master station 24. The secondary response is initiated if either communication is lost between the central server 10 and the master station 24 or if no primary response has been programmed at the central server 10.

The object IDs of all personnel badges 50 and asset tags 52 have a zero for the most significant bit. When the action button or switch is triggered then the most significant bit is set to "1" which constitutes an alert signal. When a location processor receives an alert signal it makes an audible or visual response if equipped with a means for audible or visual response.

A sub-awareness area monitoring system passes the alert signal to the central server 10. The central server 10 records the time that the alert signal was sent and looks up the programmed response for the particular object ID. The programmed response can include instructions to send a notification message to one or more monitoring clients 40, or to direct an audio message to the audio annunciator of one or more nodes 18, or to send a message to a pocket pager. The central server 10 sends notification messages to all monitoring clients 40, nodes 18 and pocket pagers as instructed by the pre-programmed response. Each monitoring client 40 that receives the notification message sounds an audible tone indicating that a notification message has been received and a pop-up window is displayed on the monitoring client 40 indicating the personnel badge 50 that has sent the alert signal and the location from where the alert signal was sent. The person at the monitoring client 40 acknowledges the alert signal by closing the pop-up window, which sends an alert acknowledgment message back to the central server 10 which records the alert acknowledgment time. An independent monitoring system 25 may also have a secondary response stored on the master station which is initiated in addition to the central station 10 response. When the secondary alert process has been acknowledged the master station 24 sends an alert acknowledgment message back to the central server 10 which records the alert acknowledgment time.

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#### Central Server and Client Communication

A top-level diagram of the communications between the central server 10 and potential clients 14, 24, 34 over the network 12 is shown in FIG. 12. There are three types of clients that are in contact with the central server 10. The first is a dependent monitoring system router 14. The router 14 is in communication with the central server 10 sending location messages for the sub-awareness area that the dependent monitoring system 15 is monitoring. The second type of client is an independent monitoring system master station 24. The master station 24 is in two-way communication with the central server 10 sending location messages for the sub-awareness area that the independent monitoring system 25 is monitoring, and primarily receiving location updates for personnel badges 50 assigned to the independent monitoring system 25 which are received from outside the sub-awareness area that the independent monitoring system 25 is monitoring. The third type of client is a network client 40. Network clients 40 primarily query the central server 10 for location and tracking data to create screen displays or reports, they do not provide location updates but they can update other data on the central server 10.

The interface between the central server 10 and the network client 40 is a Web browser interface commonly used on the Internet. The interface between the central server 10 and the dependent monitoring system router 14 or the independent monitoring system master station 24 can be web browser based or through other network communication methods. The web server 210 is developed with Internet Information Server (IIS) software, developed by Microsoft, on the central server 10 provides the necessary functionality to host a Web site that can intercept and interpret information requests or updates, call the service providers to make the necessary database queries or updates, and create a dynamic Web page responsive to the information request or update. The web server 210 can service multiple clients over an Internet or Intranet from a single central server 10. The service providers for the web server 210 are applications that can update, query and maintain databases containing information of interest to the clients.

The primary location and tracking databases on the central server 10 are as follows. The Location Update Cache 290 contains the current location of all personnel badges 50 and asset tags 52, ordered by location. The Location/Tag ID Cache 292 contains the current location of all personnel badges 50 and asset tags 52, ordered by Tag ID. Having the current location of all personnel badges 50 and asset tags 52 ordered by both location and Tag ID allows increased system performance when responding to database queries. The Rules Cache 296 contains rules defined for objects and locations such that when a rule is violated a message is sent to interested client 24, 34. The Registered Interests Cache 294 contains a cross-reference between clients 24, 34 and interests for which the client 24, 34 is registered. The Database Transaction Queue 298 contains all of the incoming and processed transactions from networked clients. The SQL Database 300 contains a record of all database change events that have occurred and their times.

The Location Update application 212 receives location updates from dependent monitoring systems 15 and independent monitoring systems 25. The location updates can be in the form of entry messages or exit messages if the monitoring system is buffered or in the form of presence messages if the monitoring system is pass-through. The Location Update application 212 updates the object ID/location pair in both the Location Update Cache 290 and the Location/Tag ID Cache 292, and also enqueues the transaction in the Transaction Queue 298.

The Interests application 214 receives interests from clients that a user would like to add to or delete from the Registered Interests Cache 294. Interests are events that a client application wants to be notified of when the event occurs. Examples of interests are alarm events and personnel badge 50 assignment changes. The Interests application 214 records the event and client that wants to be notified of the event in the Interests Cache 294 and also enqueues the transaction in the Transaction Queue 298.

The Tag Association application 218 manages the association and disassociation of personnel badges 50 and asset tags 52 to people and assets, respectively. The Tag Association application 218 receives instructions from a client and makes the appropriate updates to the Location/Tag ID Cache 292 and enqueues the transaction to the Transaction Queue 298.

The Non-Interactive Database application 220 handles all database transactions that do not require a user response. The Direct Database Access application 222 handles all transactions that require access to the SQL Database 300.

The Awareness Engine Monitor 230 constantly watches the caches for the occurrence of alarm and interest events stored in the Interests Cache 294 or violations of the rules stored in the Rules Cache 296. When an interest event occurs or a rule has been violated the Awareness Engine Monitor 230 sends an appropriate notification to the clients that have registered for that event. A flowchart of the rules processing performed by the Awareness Engine Monitor 230 is shown in FIG. 13. The process is initiated by the receipt of a location message by the web server 210 of the central server 10, as shown in step 310. When the location update is passed to the Awareness Engine Monitor 230, the following processes are performed. First, the location entry is updated in the Location/Tag ID Cache 292 to indicate a new object ID at this location, as shown in step 320. The Awareness Engine Monitor 230 then checks if any rules concern this location 322. Second, the object ID entry in the Location Update Cache 290 is updated to indicate that the object ID is located at the new location, as shown in step 330. The Awareness Engine Monitor 230 then checks if any rules concern this object ID 332. Third, the Awareness Engine Monitor 230 checks if there are any global rules, those that do not concern a particular object or location ID, triggered by this update 340. The Awareness Engine Monitor 230 then checks whether any of the rules found in steps 322, 332 and 340 are violated, as shown in step 350. If any rule was violated the Awareness Engine Monitor 230 checks if the Registered Interests Cache 294 has a client to be notified of the rule violation 352. A message is sent by the central server to any registered client indicating the rule violation that occurred 354. The client can then perform the response it is programmed to perform when the notification is received 356.

The Subscription Service application 216 is also used for event notification and alarms. The Subscription Service application 216 sends the notification message to the client that has subscribed to be notified of a particular event. An example is an independent monitoring systems 25 that wants to be informed when a personnel badge 50 assigned to the sub-awareness area being monitored by the independent monitoring system 25 is detected outside of that particular sub-awareness area. In this instance, the Subscription Service application 216 will be initiated when an assigned badge 50 of the independent monitoring system 25 is detected outside its sub-awareness area and the Subscription Service application 216 will send a location message to the independent monitoring system 25 to be used to update the local sub-awareness area database being maintained by the master station 24.

The Awareness Engine Queue Processor 224 processes all transactions in the enqueue of the Transaction Queue 298 to update the SQL Database 300. When a request is received by the Web Server 210 it is handed off to the appropriate service provider application. If the request involves a database update, the appropriate update information is placed in Transaction Queue 298. Once a transaction is successfully processed by the Awareness Engine Queue Processor 224 it is moved to the dequeue of the Transaction Queue 298. If a transaction is not successfully processed by the Awareness Engine Queue Processor 224 it is moved to a separate part of the dequeue for failed transactions. From here an Administrative Client 44 can review the transaction, make any necessary changes and requeue the transaction for processing by the Awareness Engine Queue Processor 224. An Administrative Client 44 also periodically cleans up dequeued transactions.

The data flow from the tag transmission to the appropriate database updates at the central server 10 is as follows. A personnel badge 50 or asset tag 52 transmission is detected by a receiver node 18 and the receiver node 18 generates a location message which it sends downstream. If the receiver node 18 is part of a dependent monitoring system 15 the location message is sent to the router 14 which sends the location message across the network 12 to the central server 10 without any intermediate storage. If the receiver is part of an independent monitoring system 25 it is stored at the master station 24 and the master station 24 also sends the location message across the network 12 to the central server 10. The web browser 210 on the central server 10 receives the location message. The web browser 210 passes the location message to the Location Update program which updates the Location Update cache 290 and the Location/Tag ID Cache 294 and checks the Rules Cache 296 for any actions that are to be performed based upon the update. A transaction is also sent to the Transaction Queue 298 which will be processed by the Transaction Queue Processor 224 to make a historical record of the update on the SQL Database 300.

#### Client Interfaces

The master station 24 of an independent monitoring system 25 can be a client of the central server 10. The nodes 18 of the independent monitoring system 25 receive transmissions from personnel badges 50 and asset tags 52 in the sub-awareness area covered by the independent monitoring system 25. These transmissions are converted into location messages which are forwarded to the master station 24 which updates the local sub-awareness area database and transmits the location update to the web browser 210 on the central server 10 which collaborates with the appropriate programs to update the Location Update cache 290, the Location/Tag ID Cache 292 and the SQL Database 300.

The independent monitoring system 25 has several important advantages due to its connection to the central server 10. The first advantage is that the independent monitoring system 25 can track the personnel badges 50 and asset tags 52 assigned to the independent monitoring system 25 even when they are outside of the sub-awareness area monitored by the independent monitoring system 25, as long as they are within the awareness area. All of the objects that an independent monitoring system 25 wants assigned are listed in the Interests Database 294 with the identity of the independent monitoring system to be notified. When an object is within the awareness area but outside the independent monitoring system's 25 sub-awareness area, the central server 10 will receive a location message for the object from another client. When this location message is detected by the

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Awareness Engine Monitor 230 it will recognize the interest in the Interest Database 294 and send a location message for the object to the independent monitoring system 25 using the Subscription Service application 216.

This same functionality can be used by an independent monitoring system 25 to add objects that it wants to track in its local sub-awareness area database. A message would be sent from the master station 24 of the independent monitoring system 25 to the Web Server 210 of the central server 10 to register an interest for the new object. The Interests application 214 would record the interest in the Interests Database 294 and the Awareness Engine Monitor 230 would inform the independent monitoring system 25 of any location messages received for the associated object badge/tag outside the independent monitoring system's 25 sub-awareness area.

The connection to the central server 10 also allows the independent monitoring system 25 to resolve the identity of personnel badges 50 and asset tags 52 which are not assigned to the sub-awareness area when they are detected within the sub-awareness area. The master station 24 of the independent monitoring system 25 will send a location message for an object not assigned to its sub-awareness area and also store the location message in a visitor cache. If the master station 24 does not know the identity of the object associated with the location message it will send a query to the Internet Information Server 210 of the central server 10. The Direct Database Access program 222 in the central server 10 will query the SQL Database 300 and send a response containing the identity of the object for use in the local sub-awareness area database of the independent monitoring system 25.

Connection to the central server 10 also allows a user at the master station 24 of the independent monitoring system 25 to perform location searches for any locateable entity in the awareness area known to the central server 10 or other functions that can be performed from a client 40.

A client 40 is used to access information maintained by the central server 10. A client 40 has a web browser interface through which a user communicates with the Web Server 210 of the central server 10 to query or update information maintained in the central server 10 databases. The two primary location viewing applications of the client 40 are the Personnel View and Asset View functions. The client 40 can be a computer assigned to an individual that contains the Personnel View and Asset View software packages and has access to the central server 10 via an Internet or Intranet connection.

Personnel View allows a user to locate personnel associated with personnel badges 50, to assign and deassign personnel to personnel badges for tracking in the awareness area, to maintain and update personnel information stored by the central server 10, and to perform administrative functions. When a user wishes to use the Personnel View function they must first login to the system to indicate the user's identity and to prevent unauthorized access.

A personnel search can be performed from a standard search screen or the user can set-up a list of common searches they wish to perform and simply select one of these pre-defined searches. Personnel searches can be run based on first name, last name, department, skill and location with filter options of begins with, contains, or equals. Fields maintained in the Personnel Database on the central server 10 include name, department, skill, time since badge last seen, location where badge last seen, nearest phone number to location where badge last seen, name and phone number of person taking calls for this person, and mobile phone

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number for person. When the information is displayed for the located person or persons several fields may be highlighted showing a link to additional information about the hyperlinked item. For instance, location, department, organization or skill fields could be highlighted to indicate that an explanation of the contents or codes used for each of these fields is available which the user can access by selecting the highlighted field. An edit option is also available to the user to edit any information stored in the personnel databases on the central server 10 for the user login entered or for those personnel that have authorized updates by the user login entered.

A user can also log onto Personnel View and enter status information. An out to lunch or gone home option will set the location of the badge associated with the logged on user to "Out to Lunch" or "Gone Home" respectively and provide an expected return time. The expected return time can be either a default time or default length of time from when the message was activated or can be over-ridden by a time entered by the user. A search that includes that user will return the location message and expected return time until the expected return time is passed. After the expected return time passes the normal location message will be returned for the user. A do not disturb option, if selected by the user, will display "Do Not Disturb" along with the location information for any search performed that returns the user's location. This message will continue to be displayed until disabled by the user.

Asset View allows a user to locate assets associated with an asset tag 52, to assign and deassign assets to asset tags for tracking in the awareness area. When a user wishes to use the Asset View function they must first login to the system to indicate the user's identity and to prevent unauthorized access.

An asset search can be performed from a standard search screen or the user can set-up a list of common asset searches they wish to perform and simply select one of these pre-defined searches. Asset searches can be run based on standard asset description, add-on description, asset ID, asset category, location, or vendor with filter options of begins with, contains, or equals. Fields maintained in the Asset Database on the central server 10 include asset name, asset serial number, time since tag last seen, location where tag last seen, asset owner's name and phone number. When the information is displayed for the located asset several fields may be highlighted showing a link to additional information about the hyperlinked item.

A client 40 can also be equipped to support report generation and report design. The report design function is internal to the client 40 and allows the user to customize the content of a report and the arrangement of data fields. The report generator allows the user to select a predefined report which was designed with the report designer. When the user runs the report the report generator uses a web browser interface to communicate over a network connection to the web browser 210 of the central server 10. The necessary data from the central server databases is retrieved and sent back to the client 40. The report client formats the returned data according to the report design. The user can then display, print or save the report.

It will be understood that various modifications can be made to the system disclosed in this application without changing the scope of the invention as set forth in the Claims attached hereto.

What is claimed is:

1. A system for locating and tracking tags within an awareness area including a first sub-awareness area and a

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second sub-awareness area, each tag including a transmitter configured to transmit a unique identifier periodically, and at least one tag being assigned to the first sub-awareness area, the system comprising:

- a communication network,
  - a first monitoring system associated with the first sub-awareness area, the first monitoring system comprising a receiver positioned to receive transmissions from tags positioned within the first sub-awareness area and configured to provide location messages in response to the transmissions, an intermediate location processor connected to the receiver and configured to transmit location messages from the receiver, and a master station connected to the intermediate location processor and connected to the communication network,
  - a second monitoring system associated with the second sub-awareness area and connected to the communication network, the second monitoring system being configured to transmit downstream location messages to the communication network in response to transmissions from tags positioned within the second sub-awareness area, and
  - a server connected to the communication network and configured to provide a network location message for each downstream location message associated with a tag assigned to the first monitoring system over the communication network to the first monitoring system.
2. The system of claim 1, wherein the network location message identifies the tag and the location of the tag.
  3. The system of claim 1, wherein the master station is configured to transmit master location messages to the server over the communication network in response to receipt of location messages from the intermediate location processor.
  4. The system of claim 1, wherein the master station is configured to store location messages related to tags which are not associated with the first sub-awareness area in a memory, the master station also being configured to transmit a query to the server requesting an identity of the tags which are not associated with the first sub-awareness area for which the location messages are stored in the memory based on the unique identifier of said tags.
  5. The system of claim 1, wherein the network location message provides an indication of a location of the tag associated with the first sub-awareness area.
  6. A system for locating and tracking objects within an awareness area including a sub-awareness area, the system comprising:
    - a plurality of tags, each tag being associated with an object, each tag including a transmitter configured to transmit a unique identifier periodically, at least one tag being associated with the sub-awareness area,
    - an independent monitoring system associated with the sub-awareness area and configured to provide first location messages in response to transmissions from tags positioned within the sub-awareness area,
    - a second monitoring system configured to provide second location messages in response to transmissions from tags detected by the second monitoring system,
    - a communication network coupled to the independent monitoring system and coupled to the second monitoring system, the communication network being configured to transmit first location messages and second location messages, and
    - a server connected to the communication network and configured to receive the first location messages and the

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second location messages and to provide a network location message in response to each second location message associated with a tag associated with the sub-awareness area to the independent monitoring system through the communication network.

7. The system of claim 6, wherein the second monitoring system is a dependent monitoring system.
8. The system of claim 6, wherein the second monitoring system is an independent monitoring system.
9. The system of claim 6, wherein the plurality of tags are associated with personnel and assets.
10. The system of claim 6, wherein the independent monitoring system is configured to store first location messages related to tags which are not associated with the sub-awareness area in a memory, the independent monitoring system also being configured to transmit a query to the server requesting an identity of the tags which are not associated with the sub-awareness area for which the first location messages are stored in the memory based on the unique identifier of said tags.
11. A system for locating and tracking objects within an awareness area including a sub-awareness area, the system comprising
  - a plurality of tags, each tag being associated with an object, at least one tag being associated with the sub-awareness area,
  - an independent monitoring system associated with the sub-awareness area and configured to provide first location messages in response to the detection of tags positioned within the sub-awareness area,
  - a second monitoring system configured to provide second location messages in response to the detection of tags detected by the second monitoring system, and
  - a server in communication with the independent monitoring system and the second monitoring system and configured to receive the first location messages and the second location messages and to provide to the independent monitoring system a network location message in response to each second location message associated with a tag associated with the first sub-awareness area.
12. The system of claim 11, wherein the second monitoring system is a dependent monitoring system.
13. The system of claim 11, wherein the second monitoring system is an independent monitoring system.
14. The system of claim 11, wherein the plurality of tags are associated with personnel and assets.
15. The system of claim 11, wherein the network location message provides an indication of a location of the tag associated with the first sub-awareness area.
16. The system of claim 11, wherein the independent monitoring system is configured to store first location messages related to tags which are not associated with the first sub-awareness area in a memory, the independent monitoring system also being configured to transmit a query to the server requesting an identity of the tags which are not associated with the first sub-awareness area for which the first location messages are stored in the memory based on the unique identifier of said tags.
17. A method for locating and tracking objects in an area, the method comprising the steps of:
  - establishing a first sub-area,
  - establishing a second sub-area,
  - assigning objects to the first sub-area,
  - monitoring objects in the first sub-area,
  - monitoring objects in the second sub-area, and
  - notifying a monitor of the first sub-area of the detection in the second sub-area of an object assigned to the first sub-area.

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18. The method of claim 17, wherein the notifying step includes the step of providing a location message from a monitor of the second sub-area to a server.

19. The method of claim 18, wherein the monitor of the first sub-area includes a master station and the notifying step further includes the step of providing a location message from the server to the master station.

20. The method of claim 19, further comprising the step of storing a location message associated with an unassigned object not assigned to the first sub-area in a memory of the master station upon detection in the first sub-area of the unassigned object.

21. A system for locating and tracking tags associated with objects, the tags being configured to transmit a unique identifier periodically, the system comprising:

a communication network,

a monitoring system coupled to the communications network, the monitoring system being configured to provide location data for the objects in response to transmissions from tags,

a server in communication with the monitoring system through the communications network, the server including a web server, the monitoring system being configured to provide the location data to the server, and

a client including a web browser interface configured to couple the client to the web server to enable the client to communicate with the server through the web browser interface to obtain location data for a selected object.

22. The system of claim 21, wherein the monitoring system is an independent monitoring system including a master station and the master station includes the web browser interface coupling the master station to the web server through the communication network, the master station communicating with the server through the web browser interface to obtain the location data for the selected object.

23. The system of claim 21, wherein the monitoring system is a dependent monitoring system including a router and the router includes the web browser interface coupling the router to the web server through the communication network, the router communicating with the server through the web browser interface to obtain the location data for the selected object.

24. The system of claim 21, wherein the monitoring system comprises a first monitoring system and a second monitoring system, the first monitoring system being configured to monitor objects in a first sub-area and the second monitoring system being configured to monitor objects in a second sub-area.

25. The system of claim 24, wherein the first monitoring system is configured to store location data for monitored objects assigned to the first sub-area.

26. A system for locating and tracking objects in an area, the system comprising:

a plurality of tags, each tag being associated with an object,

a monitoring system configured to provide messages in response to the detection of a tag in the area,

a server comprising a web server and an awareness engine, the server being in communication with the monitoring system and configured to receive the messages from the monitoring system, and

a client in communication with the web server to locate and track the objects in the area.

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27. The system of claim 26, wherein the awareness engine is configured to monitor changes in a status of an object.

28. The system of claim 26, wherein the web server is configured to transmit messages between the client and applications that interact with the awareness engine.

29. The system of claim 26, wherein the location and tracking databases each include a storage comprising clients and interests for which each client is registered.

30. The system of claim 26, wherein the awareness engine comprises primary location and tracking databases, an awareness engine monitor, and a database.

31. The system of claim 30, further comprising a second client in communication with the server and wherein the primary location and tracking databases include a Registered Interests Cache containing a cross-reference between the clients and interests for which each client is registered.

32. A method for processing a location message in a system for locating and tracking objects, the method comprising the steps of

receiving a location message,

updating a location entry to indicate a new object at a location,

updating an object ID entry to indicate the object ID at a new location,

evaluating the location message,

notifying a client, and

updating a database.

33. The method of claim 32, wherein the evaluating step further comprises the steps of determining whether the location message invokes any system rules, determining whether the location message violates any system rules, and notifying the client of any rule violation.

34. The method of claim 32, wherein the evaluating step further comprises the steps of determining whether the client subscribed to be notified of an event described by the location message and notifying the client of the event if the event is one for which the client subscribed to be notified.

35. The method of claim 32, wherein the receiving step includes the steps of detecting the presence of an object, generating a location message, and providing the location message to a server.

36. The method of claim 35, wherein the receiving step further includes the step of providing the location message to a router.

37. The method of claim 32, wherein the database is SQL database.

38. The method of claim 32, wherein the evaluating step comprises the step of determining whether the location message violates any rules.

39. The method of claim 32, wherein the evaluating step comprises the step of determining which client to notify of an event described by the location message.

40. A system for locating and tracking at least one object within a first area and a second area, the at least one object being assigned to the first area and including a signal transmitter which transmits object information, the system comprising:

a first monitoring system having a first memory,

a second monitoring system, and

a server in communication with the first monitoring system and the second monitoring system, the server being configured to store object and location information for the at least one object in a memory and transmit location update information for the at least one object to the first monitoring system, the first monitoring system being configured to receive object information



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from the signal transmitters within the first area, to receive location update information for the at least one object from the server, and to store the object information and location update information in the first memory.

41. The system of claim 40, wherein the second monitoring system is configured to detect the at least one object in the second area and transmit object and location information for the at least one object to the server.

42. The system of claim 40, wherein the server, first monitoring system, and second monitoring system are coupled to a communication network.

43. The system of claim 40, wherein the central storage further comprises an interests database configured to associate the location update information with the corresponding at least one object before transmitting the location update information to the first monitoring system.

44. The system of claim 40, wherein the first monitoring system further comprises a receiver, a location processor coupled to the receiver, and a master station coupled to the location processor, the receiver being configured to receive transmissions from the at least one object assigned to the first area and transmit object information to the location processor in response to the transmissions, the location processor configured to transmit the object and location information to the master station, and the master station configured to transmit the object and location information to the server.

45. The system of claim 40, further comprising at least one second object.

46. The system of claim 45, wherein the second monitoring system is configured to detect the at least one second object in the second area and transmit object and location information for the at least one second object to the server.

47. The system of claim 45, wherein the first monitoring system is configured to assign the at least one second object to the first area.

48. The system of claim 40, wherein the location update information includes information that identifies the monitoring system to which the at least one object is assigned.

49. A method for identifying, locating and tracking at least one object not previously associated with a monitoring system, the at least one object including a transmitter which transmits a unique identifier for the object, the monitoring system being in communication with a server having a central database, the method comprising the steps of:

receiving the unique identifier from a detected object;  
determining whether the detected object is associated with the monitoring system,

storing location information related to the detected object in the a memory of the monitoring system,

transmitting an identification request query to the server if the detected object is not associated with the monitoring system,

receiving an identification of the detected object stored in the central database from the server, and

storing the identification of the detected object in the memory of the monitoring system along with the location information for the detected object.

50. The method of claim 49, further comprising the steps of forwarding to the monitoring system all previous location information stored in the central database for the detected object and storing the previous location information for the detected object in the memory to enable the monitoring system to track the detected object.

51. The method of claim 49, wherein the forwarded location information includes location messages for the

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detected object related to locations outside an area monitored by the monitoring system.

52. The method of claim 50, further comprising the steps of registering an interest for the detected object with a web server of the server, and storing the interest in the central database.

53. A method for locating and tracking objects in a monitoring system, the objects configured to a unique identifier to the monitoring system, the monitoring system being configured to provide location messages for the objects, and the monitoring system providing information to a plurality of clients over a communications network, the method comprising the steps of:

storing the location messages for the objects,  
indexing the location messages by location and object,  
storing rules for the objects and locations,  
storing interests for the plurality of clients,  
evaluating the rules and location messages to determine whether a change event has occurred,  
evaluating the interests to determine which clients to notify of a change event, and notifying the appropriate clients of change events.

54. The system of claim 53, wherein the storing step comprises the step of storing the location messages in at least one of a local memory and a central memory.

55. The system of claim 53, wherein the storing step comprises the steps of storing a first subset of the location messages in a local storage and storing a second subset of the location messages in a central storage.

56. A system for monitoring objects in an area, the objects having tags configured to transmit an identifier, the system comprising:

a plurality of clients, and  
a server in communication with the plurality of clients, the server comprising a location cache comprising location data indexed by object, a location update cache comprising location data indexed by location, an interests cache, a rules cache, a change event database, a location update application for processing location updates, an interests application for processing interests and rules associated with each of the plurality of clients and objects,  
a tag association application for associating tags with objects, and  
a subscription application for notifying the plurality of clients of change events in accordance with the rules and interests.

57. The system of claim 56, wherein at least one of the plurality of clients is in communication with the server through a web browser interface.

58. The system of claim 56, wherein the plurality of clients and the server are in network communication over a global communications network.

59. The system of claim 56, wherein at least one of the plurality of clients is a second monitoring system.

60. The system of claim 59, wherein the second monitoring system is an independent monitoring system.

61. A monitoring system for use in a system for locating and tracking tags within an area, the system for locating and tracking tags including a server, the monitoring system being used to monitor a sub-area of the area, the monitoring system comprising:

a router in network communication with the server,  
at least one hub in network communication with the router and



a plurality of nodes in network communication with the hub, wherein each of the plurality of nodes monitors a portion of the sub-area for tag-identifying transmissions, receives a tag-identifying transmission, and generates a first location message based on the tag-identifying transmission, the at least one hub receives the first location message and sends a second location message based on the first location message to the router, and the router receives the second location message and sends a third location message based on the second location message to the server.

62. The system of claim 61, wherein each of the plurality of nodes further comprises a microprocessor which processes the tag-identifying transmissions.

63. The system of claim 61, wherein each of the plurality of nodes further comprises an LED.

64. The system of claim 61, wherein each of the plurality of nodes further comprises an audio annunciator.

65. The system of claim 61, wherein the first, second, and third location messages are presence messages.

66. A computer program product embodied in a computer readable medium capable of being connected to a network to operate to locate and track tags, the computer program product comprising:

- means for defining a first area,
- means for defining a second area,
- means for assigning tags to the first area,
- means for monitoring tags in the first area,
- means for monitoring tags in the second area, and
- means for notifying a monitor of the first area when a tag assigned to the first area is detected in the second area.

67. A computer memory encoded with executable instructions representing a computer program for causing a computer system connected to a network to operate as a system for locating and tracking tags, the system for locating and tracking tags operating to:

- monitor tags in a first area,
- monitor tags in a second area, and
- notify a monitor of the first area when a tag assigned to the first area is detected in the second area.

68. The computer memory of claim 67, wherein the monitor of the first area is a client coupled to the network.

69. The computer memory of claim 68, wherein the client includes a web browser.

70. A computer database product for maintaining information related to objects in an area, the information being maintained for use in a system for locating and tracking the objects, the computer database product embodied in a computer readable medium, the computer database product comprising:

- a location cache,
- a location update cache,

an interests cache, and

a rules cache, wherein the location cache includes location data indexed by object, the location update cache includes location update data for the objects indexed by location, the interests cache includes interests indexed by interest, and the rules cache includes rules indexed by at least one of object and location.

71. A computer program product embodied in a computer readable medium capable of being connected to a network to operate as a system for locating and tracking objects, the computer program product comprising:

- a location update application,
- an interests application, and
- an awareness engine monitor, wherein the location update application receives location updates, the interests application receives interests, and the awareness engine monitor monitors changes in the location of tags.

72. The computer program product of claim 71, wherein the awareness engine monitor receives a location update indicating a location for an object, updates a location cache to indicate that the object is at the location, and determines whether a message should be generated based on the location of the object and the interests.

73. The computer program product of claim 72, further comprising a subscription service application which sends a message to a client based on the location of the object and the interests.

74. The computer program product of claim 73, wherein the message to a client indicates that the object has been detected outside of a valid area.

75. A computer program product embodied in a computer readable medium capable of being connected to a network to operate as a user interface for communicating with a system for locating and tracking tags associated with objects, the computer program product comprising:

- a view application, and
- a query application, wherein the view application locates objects associated with tags, assigns tags to objects, deassigns tags from objects, updates object information, and the query application searches for object information based on selected criteria.

76. The computer program product of claim 75, wherein the query application searches for object information based on pre-defined criteria.

77. The computer program product of claim 75, further comprising an edit application which edits object information.

78. The computer program product of claim 75, further comprising a report application which displays object information based on selected criteria.

79. The computer program product of claim 75, further comprising a web browser interface.

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